Open Access

*Original Paper*
*J. Glob. Innov. Agric. Sci., 2026, 14(2):498-508*
*ISSN (Online): 2788-4546; ISSN (Print):2788-4538*
*DOI: https://doi.org/10.22194/JGIAS/26.1844*
*http://www.jgiass.com*

Society for Innovative Agriculture

# Growth Response of Agarwood Seedlings (*Aquilaria malaccensis Lamk*) in Various Planting Media: Conservation Approaches

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Agarwood (*Aquilaria malaccensis Lamk*) is a tree species with high economic value due to its resin, widely used in the perfume, pharmaceutical, and religious industries. However, overexploitation and habitat degradation have led to a significant decline in its natural population. This study was conducted using a controlled experiment to evaluate the effects of various planting media on the growth of A. malaccensis seedlings. The experiment employed a Completely Randomized Design (CRD) with seven media combinations and three replications, using 84 seedlings in total. The results showed that the combination of topsoil, peat, and river sand yielded the highest survival rate (100%) and significantly better growth performance compared to other treatments, with average plant height of 28.7 cm, stem diameter of 0.29 cm, and 27.4 leaves. This medium supports optimal growth by combining organic nutrients (peat), structural stability (topsoil), and effective drainage (river sand). Other viable alternatives include peat + river sand or topsoil + peat, depending on local availability. The findings offer a practical, evidence-based model for sustainable agarwood cultivation and a replicable approach to ex-situ conservation.
**Keywords:** Agarwood (*Aquilaria malaccensis* Lamk), ethnobotanical studies, planting media, conservation.

## INTRODUCTION

*Aquilaria malaccensis Lamk* is a tropical perennial tree known for producing agarwood resin, a high-value non-timber forest product (NTFP). This resin is highly prized in various industries, including perfumes, pharmaceuticals, cosmetics, and religious rituals, especially in Asia and the Middle East. Due to its high market demand, this species has been subjected to extensive harvesting from wild populations, pushing it toward scarcity. It is currently listed under Appendix II of CITES, indicating that although not necessarily threatened with extinction, its trade must be controlled to avoid utilization incompatible with its survival (Riawati et al., 2022; Irianto, 2014). Conservation of A. malaccensis is now a pressing issue both globally and regionally.

Habitat loss and illegal harvesting remain the primary drivers of population decline for A. malaccensis in its natural range. In Indonesia, the species occurs naturally in Sumatra, Kalimantan, and Papua. However, deforestation caused by mining, agriculture, and infrastructure development has significantly reduced its habitat. Moreover, there is a lack of standardized propagation practices to support reforestation or ex-situ cultivation programs. Studies have emphasized that the species faces a high conservation risk due to limited natural regeneration and insufficient community-based conservation initiatives (Setyaningrum & Saparinto, 2014; Muna & Prayoga, 2024). Thus, an integrated approach that combines conservation and cultivation efforts is urgently needed.

On a global scale, several countries that cultivate or harvest agarwood, such as India, Bangladesh, and Malaysia, are also struggling to ensure sustainable management of A. malaccensis. In India, soil quality and the presence of natural infections significantly affect agarwood production potential (Gogoi, 2021). In Bangladesh, agarwood has been introduced as an agroforestry component to enhance farmer livelihoods and biodiversity conservation (Samiul & Talucder, 2016). However, many of these efforts lack standardization in nursery practices, especially in selecting suitable growing

Madiyawati, M., Sudomo, M.F.A., Rosdiana & Asia, K.V. (2026). Growth Response of Agarwood Seedlings (*Aquilaria malaccensis* Lamk) in Various Planting Media: Conservation Approaches. *Journal of Global Innovations in Agricultural Sciences, 14*(2), 498-508.
[Received 8 Sep 2025; Accepted 17 Nov 2025; Published 11 Jan 2026]
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media. These international experiences provide insights into the necessity of context-based, efficient propagation strategies that align with ecological conditions and local resources.

Ex-situ conservation has become one of the key strategies for protecting endangered plant species like A. malaccensis. This method involves cultivating plants outside their natural habitat, such as in botanical gardens, nurseries, or community plantations. Ex-situ efforts complement in-situ conservation by preserving genetic diversity and supplying healthy seedlings for forest restoration. However, the success of ex-situ conservation greatly depends on the choice of planting media, which directly influences plant survival, growth rates, and eventual productivity (Kharnaior & Thomas, 2021). Selecting the optimal medium is thus crucial to ensure healthy early-stage development and efficient resource use.

Many previous studies have focused on in-vitro propagation techniques, including callus induction, shoot multiplication, and secondary metabolite production in laboratory conditions. For instance, Jayaraman et al. (2014) explored the effects of plant growth regulators and pH levels on callus formation. Other studies utilized bioreactors such as RITA® and bubble columns for shoot culture multiplication (Esyanti et al., 2019; Hapsari et al., 2021). Additionally, methyl jasmonate and fungal extracts have been used to induce agarwood compound formation in shoot cultures (Faizal et al., 2021). While these studies offer important biotechnological insights, they do not adequately address the practical aspects of seedling establishment in field conditions using locally available soil media.

Despite the extensive laboratory-based research, there exists a significant research gap in understanding the effects of different natural soil media on the ex-situ growth of A. malaccensis seedlings. To date, few empirical studies have tested various combinations of soil, peat, and sand—components that are commonly available in many tropical regions, especially in Indonesia. Since the early growth stage is critical for plant survival, the lack of field-based studies on planting media selection creates an obstacle for large-scale cultivation and conservation planning. Bridging this gap would provide evidence-based solutions to community nurseries and forestry agencies.

This study introduces a novel approach by evaluating multiple combinations of natural soil-based media (topsoil, peat, and river sand) for cultivating A. malaccensis seedlings in an ex-situ nursery setting. Unlike previous in-vitro experiments, this field-based experiment offers practical outcomes that are easily replicable by local communities, especially in rural areas with limited resources. By using locally available materials, the proposed method promotes sustainability and cost-effectiveness. Furthermore, the study aligns with community-based conservation principles and supports local economic development through sustainable agarwood cultivation.

In local Indonesian contexts, particularly in Central Kalimantan, the availability of peat and river sand provides an opportunity to design media mixes that suit the agroecological conditions of the region. However, in the absence of standardized recommendations, farmers and local conservation agencies often rely on trial and error, which results in inconsistent seedling quality. The findings from this study are expected to offer site-specific guidance on how to optimize seedling growth using combinations that reflect both agronomic suitability and ecological sustainability. This approach contributes to developing a nursery system that can be adopted by smallholders and forest management units alike.

At the national level, this research supports Indonesia's broader agenda to conserve its biodiversity through scientific innovation. Identifying the best performing planting media can inform official guidelines for agarwood seedling propagation and align conservation goals with livelihood improvement. Furthermore, producing high-quality seedlings that can survive in degraded environments or marginal lands can enhance restoration success and reduce pressure on natural populations. Thus, improving nursery practices is not only an ecological necessity but also a socio-economic imperative in tropical forest management.

In conclusion, selecting the right planting medium is fundamental to improving seedling growth, survival, and resin production in A. malaccensis. A well-structured medium can provide balanced nutrients, adequate aeration, and proper moisture retention—conditions that are vital for robust seedling establishment. These attributes are essential for scaling up ex-situ conservation efforts and facilitating successful reintroduction programs under in-situ strategies. The integration of ecological, practical, and economic factors in media selection can significantly enhance the sustainability of agarwood cultivation systems.

Therefore, this study aims to identify the most effective planting media combination for the ex-situ conservation and cultivation of Aquilaria malaccensis Lamk seedlings using local materials. The findings are expected to contribute to long-term conservation efforts, promote sustainable agarwood production, and empower local communities through accessible and science-based nursery practices.

## MATERIALS AND METHODS

This study is an experimental study using a method designed to evaluate the influence of various planting media on the growth of agarwood seedlings (*Aquilaria malaccensis Lamrk),* as well as its relevance in supporting conservation efforts of this species.

***Tools and Materials*:** Agarwood seedlings aged 2 months, Polybag size 10 cm x 15 cm, top soil planting media, peat from Taruna Jaya Village, Pulang Pisau Regency and

Kahayan river sand. The equipment used in this study is a nursery rack, a simple green house, a bucket, and a dipper. Permanent marker l for treatment marking (codification). meter or bar to measure the height of the seedlings. Calipers to measure the diameter of the seedlings. Camera for documentation.

***Experimental Design*:** The study used a Non-Factorial Complete Random Design (CRD) consisting of 7 levels of treatment. Each treatment consists of 4 seedlings with 3 repeats, so that the number of seeds used is 4 x 7 x 3 = 84 agarwood seedlings.

The treatment tested was a combination of plant media with a ratio of 1: 1 for each treatment as follows:

G : Peat G+T: peat+ top soil
T : Top Soil G+S: peat+river sand
S: River Sand T+S: Top Soil + river sand
G+T+S: peat +top soil+river sand

***Research Procedure*:**

***Initial Preparation*:** Prepare the type of planting medium to be tested. Covering soils, a mixture of top soils, peat and river sand and conducting soil analysis of the chemical and physical properties of the planting medium. Next, select uniform agarwood seedlings in good size and condition and prepare the seedbed, the necessary equipment, including polybags, measuring instruments (such as rulers and calipers), and other equipment for plant care.

***Manufacture of planting media*:** The planting medium is cleaned to avoid contamination. Fill a 10 x 15 cm polybag with various predetermined planting media and plant agarwood seedlings in polybags that have been filled with planting media according to the treatment and repetition according to the design used.

***Plant Care*:** Water regularly according to the needs of the plant and the type of planting medium used. Observe the condition of the plant at regular intervals to detect symptoms of stress, growth disorders, or pest and disease infestations.

***Plant Growth Measurement*:** Measure the growth of agarwood seedlings periodically, every 15 days for 3 months. Measure the height of the plant from the surface of the planting medium to the tip of the top shoots using a ruler. Stem diameter, by measuring the stem diameter ± 1cm from. the surface of the planting medium with calipers and counting the number of leaves during the research period.

***Data Analysis*:** This study uses Randomized Complete Block Design (RCBD) with the following mathematical equations (Mattjik and Sumertajaya, 2006):

$$Yij = \mu + \tau i + \varepsilon ij$$

where: Yij = Observation results on the ith and j repetitions; μ = Common middle value; τi = Effect of the i-treatment; εijk = Effect of experimental error on the i-i treatment and the j-repetition

The data is presented descriptively in the form of tables and figures. The data is processed with the SPSS (Statistical Program for Social Science) for Windows computer software. The measurement data was analyzed using a variety analysis (ANOVA). If the results of the fingerprint analysis show a real difference, it is followed by the Honest Real Difference Follow-up Test (BNJ) at the level of 1% and 5%. to the average value of growth.

## RESULTS AND DISCUSSION

***Growth of Agarwood Plants with Planting Media Treatment*:** A good growing medium is a medium that is able to provide sufficient amounts of water and nutrients for the growth of seedlings. It can be found in soils with good air and water management, have stable aggregates, good water holding ability and sufficient space for rooting (Satria, et al., 2025)

Each plant in its natural habitat has a different growing place both in terms of its chemical and physical properties. With these conditions, each plant is able to adapt to a certain tolerance. The planting medium used in the study is a combination of top soil (top soil/fertile soil), peat and river sand as presented in Figure 1.

Top soil Peat River sand

**Figure 1. Planting Media**

From Table 1, in general, top soil has quite good fertility characteristics (Duncan, 2011, Pérez, et al., 2014, Panpatte, & Jhala, 2019), have the potential to be used in planting activities. Peat soils, although they have a very high content of organic matter, require special management to overcome the high acidity levels and availability of certain macronutrients (Sasli, 2011).

River sand has very low fertility, making it less suitable for agricultural activities without significant fertility restoration efforts. The combination of the three planting media above is able to provide optimal results for plant growth. Top soil provides sufficient nutrients and good structure to support plant roots (Warren et al., 2015; Putriawan., et al 2024; Mattila dan Häkkinen, 2025). Peat increases the organic matter content needed by plants and helps retain moisture around the roots (Asrofi, R. A., 2024). River sand adds aeration to the medium, thereby improving drainage and preventing standing water that can damage roots (Kaur et al., 2017; Gue, 2022; Chaudhary et al., 2022; River Sands 2023; Nunes et al., 2025; Abbas et al., 2025) In seedbeds, plant growth is usually measured with several key parameters that include vegetative aspects to determine the health conditions and development of young plants. These parameters include

**Table 1. The results of the planting media analysis are presented in.**

| Parameter | Topsoil Value | Criteria | Peat Value | Criteria | River Sand Value | Criteria |
|---|---|---|---|---|---|---|
| pH $H_2O$ (1:5) | 6.21 | Slightly Acidic (SA) | 4.45 | Very Acidic (VA) | 4.93 | Moderately Acidic (MA) |
| pH KCl (1:5) | 5.82 | Neutral | 4.00 | Acidic (A) | 4.33 | Neutral |
| Total N (%) | 0.21 | Low (L) | 0.96 | Very High (VH) | 0.32 | Low (L) |
| Organic C (%) | 2.46 | Low (L) | 48.83 | Very High (VH) | 0.19 | Very Low (VL) |
| C/N Ratio | 11.76 | Low (L) | 50.82 | Very High (VH) | 0.59 | Very Low (VL) |
| P-Bray (ppm) | 130.82 | Very High (VH) | 734.25 | Very High (VH) | 10.02 | Low (L) |
| Exchangeable K (me/100g) | 2.86 | Very High (VH) | 1.08 | Very High (VH) | 0.01 | Very Low (VL) |
| Exchangeable Ca (me/100g) | 12.35 | High (H) | 18.34 | High (H) | 0.29 | Very Low (VL) |
| Exchangeable Mg (me/100g) | 0.09 | Very Low (VL) | 0.11 | Very Low (VL) | 0.12 | Very Low (VL) |
| Exchangeable Na (me/100g) | 0.09 | Very Low (VL) | 0.35 | Low (L) | 0.03 | Very Low (VL) |
| Cation Exchange Capacity (CEC) (me/100g) | 25.32 | High (H) | 81.86 | Very High (VH) | 22.75 | Low (L) |

Source: *BPT (2005)*

*Description*: SM (Very Sour), M (Sour), S(Medium), ST(Very High), SR(Very Low), R (Low), AM (Slightly Sour)

plant height, stem diameter and number of leaves (Hartati, Roini, & Rodianawati, 2021; Dewi, & Prasetyo, 2022; Dewi, & Prasetyo, 2022).

The following is the performance of the growth of agarwood seedlings from the beginning of the study until the age of approximately 4 months can be described in Figure 2.

**Figure 2. Growth of agarwood seedlings with different planting media**

**Table 2. Average Growth and % Life of Agarwood Plants.**

| Treatment | Tall | Diamater | Number of leaves | Growth | |
|---|---|---|---|---|---|
| | | | | % off | % live |
| Top soil | 10,079 | 0,16 | 11,958 | 0 | 100 |
| River sand | 9,645 | 0,143 | 10,681 | 8,33 | 91,67 |
| Peat | 24,448 | 0,234 | 17,523 | 8,33 | 91,67 |
| Top soil+River sand | 19,542 | 0,278 | 18,278 | 0 | 100 |
| Top soil+peat | 30,662 | 0,301 | 29,417 | 8,33 | 91,67 |
| Peat+river sand | 26,617 | 0,303 | 23,639 | 0 | 100 |
| Top soil+peat+river sand | 28,735 | 0,286 | 27,361 | 0 | 100 |

Remarks: The number accompanied by the same letter is not significantly different in the 5% BNJ test.
ns : non-significant, HST = Day After Planting

**Table 3. HSD Test Results of Agarwood Plant Diameter Growth.**

| Treatment | Stem diameter on the day after planting (HST) | | | | | |
|---|---|---|---|---|---|---|
| | 15 HST | 30 HST | 45 HST | 60 HST | 75 HST | 90 HST |
| Top soil | 0,070 | 0.077 A | 0,086 | 0,234 | 0.323 ab | 0.257 A |
| River sand | 0,063 | 0.071 A | 0,079 | 0,240 | 0.260 A | 0.289 ab |
| Peat | 0,076 | 0.108 ab | 0,132 | 0,413 | 0.442 ab | 0.510 ab |
| Top soil+River sand | 0,295 | 0.120 b | 0,135 | 0,410 | 0.431 b | 0.475 c |
| Top soil+peat | 0,152 | 0.147 b | 0,173 | 0,484 | 0.548 b | 0.609 c |
| Peat+river sand | 0,139 | 0.150 b | 0,172 | 0,503 | 0.552 b | 0.618 c |
| Top soil+peat+river sand | 0,092 | 0.145 ab | 0,169 | 0,169 | 0.526 b | 0.572 bc |
| S.S | Ns | 0,061 | Ns | Ns | 0,248 | 0,187 |

Remarks: The number accompanied by the same letter is not significantly different in the 5% BNJ test.
ns : non-significant, HST = Day After Planting

Based on the results of the study which includes the measurement of plant height, stem diameter, number of leaves, and the percentage of live plants, we can analyze the most suitable planting medium for the cultivation of agarwood seedlings. The results of the average observations can be seen in Table 2.

Maximum plant height growth on top soil + peat planting medium treatment. Meanwhile, the minimum plant height growth occurs in single planting medium top soil and river sand. The high growth of plants due to the treatment of different planting media ages 15 HST to 75 HST showed the highest yields, top soil + peat + river sand, and top soil + peat showed the highest yield. Single media treatment of top soil and river sand had lower values, and showed significant differences. Whereas 90 HST there was no significant difference between the treatment (ns), although the top soil+peat (47,000 cm) and top soil+peat+river sand (44,667 cm) treatments showed the highest results. Although there was no significant difference, the combination of planting media still showed higher growth.The optimal combination of planting media, especially topsoil + peat, provides the best results in the tall growth of agarwood plants. The use of a single medium, such as river sand or topsoil, provides less than optimal results compared to a combination of media (Dinata, 2018, Wahyu Winantha., et al., Inonu., et al., 2020).

***Agarwood Plant Stem Diamater*:** The stem diameter indicates the thick growth of the stem of the agarwood plant and is an indicator of the strength and resistance of the plant. Media that supports good drainage, such as a mixture of sand and peat, can help increase the diameter of the stem because it allows the roots to function optimally in absorbing water and nutrients (Soeharyo., 2005., Ardian, Latifah, & Sepriani, D., 2013, Marlina, & Masganti, 2017, Wahyu, & Suryanti, 2019). A larger stem diameter is also a sign that the plant has a strong structure and is ready to support the production of agarwood resin (Karyantara., 2009, Wangiyana, Nurwati & Yuliana., 2017).

The results of the variety analysis (ANOVA) of the growth data of agarwood plant diameter showed that the planting medium had a significant influence on the diameter of the agarwood plant. The observation results indicated that there was a very real difference between the treatments, so it was followed by the Honest Real Difference (BNJ) test to see which treatment had the most effect.

From the above results, it can be concluded that the combination of planting media, especially those that combine fertile soil with other media such as river sand or peat, gives the best results for the stem diameter of agarwood plants. A balanced combination of media in terms of drainage, nutrients, and organic matter is essential for optimal stem growth (Widodo et al. (2016). Meanwhile, the use of river sand as the only growing medium results in the lowest stem

**Table 5. BNJ Test Results of Agarwood Plant Number Leaf Growth.**

| Treatment | Stem diameter on the day after planting (HST) | | | | | |
|---|---|---|---|---|---|---|
| | **15 HST** | **30 HST** | **45 HST** | **60 HST** | **75 HST** | **90 HST** |
| Top soil | 7.33 ABC | 14.33 ab | 13,33 | 13,33 | 12.33 A | 12.00 to |
| River sand | 6.00 to 6.00 to | 10.67 A | 11,67 | 12,00 | 12.00 to | 12.75 A |
| Peat | 7.00 ab | 15.67 ab | 18,00 | 19,67 | 21.67 ab | 22.83 ab |
| Top soil+River sand | 7.67 p | 17.33 cc | 18,67 | 21,33 | 22.67 cd | 22.92 c |
| Top soil+peat | 9.33 BC | 23.33 BC | 27,33 | 35,33 | 39.33 bcd | 34.69 BC |
| Peat+river sand | 8.67 cd | 19.67 c | 19,67 | 27,33 | 32.67 cd | 38.50 c |
| Top soil+peat+river sand | 11.00 abc | 23.33 BC | 27,00 | 30,33 | 34.33 ABC | 42.42 ab |
| S.S. | 2,167 | 6,352 | Ns | Ns | 12,172 | 14,572 |

Remarks: The number accompanied by the same letter is not significantly different in the 5% BNJ test.

diameter, indicating a lack of essential nutrients for the growth of agarwood plants.

***Number of leaves of Agarwood Plant*:** The number of leaves is an important parameter for measuring photosynthesis, which directly affects the growth of agarwood. The greater the number of leaves, the greater the plant's ability to photosynthesize and produce energy for growth (Rahmah, N., 2014, Sa. Nutrient-rich and water-sufficient media conditions will support the development of more and larger leaves. Other factors such as light intensity and water quality also affect the number of leaves that grow on agarwood plants.

The results of the variety analysis for the growth of the number of leaves of the agarwood plant show that the treatment of the planting medium has a very significant influence and needs to be complemented by a follow-up test of the Honest Real Difference (BNJ) on the growth of the number of agarwood leaves. This indicates that the physical and chemical properties of the planting medium have a major contribution to the process of photosynthesis, vegetative growth, and leaf development.

The results of the Honest Real Difference (BNJ) test on the average diameter of agarwood plants showed a significant influence of various planting media treatments. For more details, see Table 5.

Planting media top soil and river sand as the single medium showing the number of leaves produced was lower compared to other media throughout the observation time. At 90 HST, top soil has a number of leaves of 12.00, while river sand reaches 12.75. Peat planting medium yielded better results than other single media, with a number of leaves of 22.83 in 90 HST. It also shows that peat media supports leaf growth through the availability of nutrients and moisture. Meanwhile, the combination of planting media gave the best results in the combination of top soil + peat (34.69 leaves at 90 HST) and top soil + peat + river sand yielding 42.42 leaves at 90 HST.

The combination of fertile soil and peat is the most optimal in supporting the number of leaves of the agarwood plant. This combination of media provides enough nutrients and organic matter for leaf growth. A single medium, especially river sand, produces a smaller number of leaves due to nutrient limitations. Overall, the use of a balanced combination of media, nutrients, and drainage is essential for the vegetative growth of agarwood plants in seedbeds.

***Conservation Approach*:** The conservation approach in agarwood cultivation emphasizes the critical importance of maintaining ecological balance and ensuring sustainability through the responsible management of planting inputs and site conditions. In this context, the use of a combination of topsoil, peat, and river sand has proven to be the most effective in supporting both the growth and survival of Aquilaria malaccensis Lamk. seedlings. The study showed that this specific media combination achieved a 100% success rate in seedling survival while also producing high vegetative growth, with an average plant height of 28.7 cm, stem diameter of 0.29 cm, and a total of 27.4 leaves. This outcome demonstrates not only the physical suitability of the media components but also the ecological rationale behind their integration: topsoil provides structure and nutrients, peat improves organic content and moisture retention, and river sand enhances drainage and root aeration. Together, these elements form a medium that promotes sustainable plant development while minimizing the risk of seedling failure.

Furthermore, the use of peat as a planting medium holds significant conservation potential, particularly in relation to peatland ecosystems. While peatlands are often degraded or overexploited, integrating peat into nursery systems in a controlled manner can contribute to their preservation. Peat-based cultivation practices, when properly managed, can avoid contributing to further environmental degradation and may instead align with broader peatland conservation goals. This ecological synergy opens opportunities for local communities to be actively involved in sustainable cultivation practices that support peat conservation. Through education, outreach, and participatory nursery management, communities living near peat ecosystems can be empowered to both conserve and benefit from peat resources, promoting inclusive and ecologically responsible development (Dommain et al., 2010; Putri, 2017; Smith et al., 2020; Tan et al., 2022; Maimunah & Fahrimal, 2023).

The combined planting medium also plays a critical ro le in supporting conservation through its contribution to land-use efficiency and seedling resilience. The high survival rates observed in treatments using mixed media make it a reliable choice for scaling up propagation efforts in nurseries and reforestation programs. By improving root structure, water-holding capacity, and nutrient uptake simultaneously, this media combination reduces the likelihood of failure in both nursery and field conditions. As such, it can be proposed as a standard medium in conservation nurseries aiming to produce high-quality agarwood seedlings for ecosystem restoration and commercial plantations.

Ex-situ conservation serves as an essential strategy in the protection of threatened species such as Aquilaria malaccensis, particularly in response to the pressures of overharvesting and habitat degradation. The ex-situ approach includes nursery propagation, experimental cultivation, and the development of inoculation technologies to stimulate agarwood resin production. In this framework, selecting the right planting medium becomes a foundational step, as it determines the vigor, viability, and adaptability of the seedlings once reintroduced into natural habitats. The use of topsoil, peat, and river sand in equal proportions, as validated in this study, represents an evidence-based practice for ex-situ conservation that aligns with restoration goals. This medium not only enhances seedling health in the nursery phase but also prepares them for eventual replanting in in-situ conditions—closing the loop between cultivation and ecosystem rehabilitation (Braverman, 2014; McGowan et al., 2017; Wahyudi & Subiakto, 2018; Mestanza-Ramón et al., 2020).

In practice, ex-situ conservation of agarwood contributes to multiple objectives. It helps increase population numbers of Aquilaria spp. through the propagation of superior seedlings, provides sustainable sources of agarwood without further degrading natural forests, supports applied research and technological development for resin production, and reduces pressure on wild populations. In addition, this approach facilitates the integration of conservation science with local knowledge systems, allowing for the participation of indigenous and rural communities in managing forest biodiversity and deriving benefits from sustainable agarwood cultivation (Soedjito & Siregar, 2010; Sitepu et al., 2011; Yamani et al., 2017; Piñon & Reyes, 2021; Yen et al., 2024).

Ultimately, the conservation approach adopted in this study underscores the importance of using a mixed-media planting strategy not just for agronomic performance, but also for its environmental integrity and cultural relevance. It reflects a commitment to sustainability by balancing biological success with ecosystem preservation and community empowerment. The use of a planting medium composed of topsoil, peat, and river sand offers a scalable and adaptable solution for nurseries, restoration programs, and agarwood cultivation initiatives, providing a scientific foundation for future policies and practices that prioritize ecological resilience and long-term species survival.

***Conclusion*:** The results of this study confirm that the use of a planting medium consisting of a combination of topsoil, peat, and river sand in a 1:1:1 ratio provides the most optimal growing conditions for Aquilaria malaccensis Lamk seedlings in ex-situ nursery environments. This media mixture achieved the highest plant height (28.7 cm), stem diameter (0.29 cm), and number of leaves (42.4) with a 100% survival rate, significantly outperforming single-media treatments such as topsoil or river sand alone. These results highlight the importance of combining soil components that offer complementary physical and chemical properties—nutrient-rich topsoil supports root anchoring and mineral uptake, peat enhances organic matter and water retention, while river sand improves aeration and drainage. The success of this combination demonstrates the feasibility of using simple, locally available materials to achieve high-quality seedling growth, offering an affordable and effective solution for community-based agarwood propagation. Moreover, this planting medium supports the ecological principles of species-specific habitat simulation and emphasizes the role of soil health in early plant development, which is crucial for ex-situ conservation efforts preparing seedlings for eventual reintroduction into natural forest ecosystems.

Beyond the technical findings, this research embodies a set of broader conservation values. It offers an applicable, science-based strategy to preserve an economically and ecologically important species, aligning closely with the goals of biodiversity protection and restoration. By utilizing accessible local resources, this study promotes sustainable practices, integrates traditional soil management knowledge, and strengthens community empowerment through low-cost, replicable methods. These efforts contribute meaningfully to global environmental and development targets, particularly in supporting the Sustainable Development Goals (SDGs) related to poverty alleviation, climate action, and life on land.

Looking forward, future research is recommended to assess the long-term performance of seedlings planted in their natural habitats, including survival rates, resin productivity, and resistance to environmental stressors. Further exploration into variations in media composition across ecological zones, and integration of biological inducers to enhance resin formation, would deepen our understanding of optimal cultivation methods. This study thus lays a practical and ethical foundation for sustainable agarwood conservation—bridging the gap between science, local wisdom, and community resilience.

***Acknowledgements*:** The authors would like to express their sincere gratitude to the University of Palangka Raya, particularly the Institute for Research and Community Service (LPPM UPR), for providing funding support for the implementation of this research activity. Appreciation is also

extended to all individuals and institutions who contributed their time, expertise, and assistance during the implementation of the Research Assignment Program for the Acceleration of Professorship, thereby ensuring the success of this work.

***CRediT author statement*:** Milad Madiyawati, Muh. Fadhil A. Sudomo, Rosdiana, and Kambang Vetrani Asia, Patricia Erosa Putir contributed equally to the design, implementation, data analysis, and writing of this research article.

***Conflicts of Interest*:** Informed consent was obtained from all individual participants involved in this research, where applicable.

***Ethical statement*:** All authors have reviewed and approved the final version of this manuscript and consent to its publication.

***Availability of Data*:** Data will be available upon request.

***Consent to participate*:** All authors participated in this research study.

***Informed consent*:** Informed consent was obtained from all individual participants included in this research.

***Consent for Publication*:** All authors agreed to the publication of this research.

***Funding*:** The authors receive any financial support from University of Palangka Raya, especially the UPR Community Service Institute (LPPM) for providing an allocation of funds for the implementation of this research activity.

***SDGs addressed*:** No Poverty, Zero Hunger, Climate Action, Life on Land.

***Policy referred***: Convention on Biological Diversity (CBD); CITES Appendix II; United Nations Sustainable Development Goals (SDGs 12, 13, 15); Indonesian National Biodiversity Strategy and Action Plan (IBSAP).

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